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Electric Corporation**

January 14, 1997

Law and Environmental
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Fax (412) 642 5266The Commissioner of Patents and Trademarks
Washington, DC 20231

W.E. Case No.: T29649
 Applicant(s): MICHAEL S. BRIESCH; JORGE J. ALBA
 Title: COMBUSTION TURBINE WITH FUEL HEATING SYSTEM

Sir:

Transmitted herewith, for filing, is the above-identified patent application along with:

4 sheets of drawings (Fig. 1-4)
 An assignment of the invention.
 Declaration & Power of Attorney.
 Information Disclosure Statement

The fees involved are calculated as follows:

	<u>Excess Number</u>	<u>Rate</u>	<u>Amounts</u>
Basic Fee		\$770	\$770
Independent claims in excess of 3	0	x \$80	0
Claims in excess of 20	1	x \$22	22
Multiple dependent claims	0	@ \$260	0
Surcharge	0	\$130	0
Assignment Fees		@ \$ 40	\$40
Charge our Deposit Account No. 23-1325			<u>\$832</u>

The Commissioner is hereby authorized to charge any additional fees included in 37 CFR 1.16 and 1.17 which may be required, or credit any overpayment to Account No. 23-1325. No authorization is given to charge any patent issue fee included in 37 CFR 1.18.

**WESTINGHOUSE ELECTRIC CORP.
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08/787718^ACOMBUSTION TURBINE WITH FUEL HEATING SYSTEMBACKGROUND OF THE INVENTION

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The invention relates to combustion turbine power plants and more particularly to fuel heating systems for combustion turbine power plants.

10 It is known in the art to indirectly utilize the exhaust gas from a combustion turbine to preheat combustion air and fuel in combustion turbine systems. In prior systems intermediate heat exchangers are utilized in which an intermediate fluid, such as, water is heated by the exhaust gas from the combustion turbine which in turn heats the fuel for combustion.

15 This type of system can be more costly due to the additional heat exchanger and may not fully utilize the heat from the exhaust gas.

One prior art approach disclosed in United States Patent No. 4,932,204 recovers heat available in the exhaust gas of the combustion turbine by increasing the water flow through the economizer section to a rate in excess of that required to match the steam production rate in the evaporator section. The excess water flow is withdrawn from the heat recovery steam generator at a temperature approaching the evaporator temperature and used to preheat the fuel delivered to the combustor of the combustion turbine.

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Another approach proposed to preheat fuel is to use waste heat from the combustion turbine rotor air cooler to raise the fuel temperature to above 600°F. One draw back to using the rotor air cooler waste energy is that it requires a complex arrangement and sophisticated controls to maintain relatively constant fuel temperature while simultaneously maintaining the required cooling for the rotor over the possible range of operating loads for the turbine.

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Therefore, what is needed is a combustion turbine fuel

heating system that is simple, economical, will allow the fuel to be heated above 600°F, if desired, and can be used in a simple or combined cycle combustion turbine power plant.

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SUMMARY OF THE INVENTION

The combustion turbine system comprises a fuel line connected to the combustor with a portion of the fuel line being disposed in heat transfer relationship with the exhaust gas from the combustion turbine so that the fuel may be heated by the exhaust gas prior to being introduced into the combustor. The system may also comprise a fuel by-pass control system for mixing unheated fuel with the heated fuel to control the temperature of the fuel being introduced into the combustor.

A portion of the fuel line may be disposed in the exhaust stack of the combustion turbine or it may be disposed in a separate flow path so that the amount of exhaust gas flowing in heat transfer relationship with the fuel line may be controlled or terminated. A portion of the fuel line may also be disposed in a section of a heat recovery steam generator or in a separate flow path connected to the heat recovery steam generator so that the amount of exhaust gas flowing in heat transfer relationship with the fuel line may be similarly controlled.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood when considered in view of the description of the preferred embodiment taken together with the following drawings wherein:

Figure 1 is a schematic of the combustion turbine system with a portion of the fuel line disposed in the exhaust stack of the combustion turbine;

Figure 2 is a schematic of the combustion turbine system with a portion of the fuel line disposed in a separate section of the exhaust stack of the combustion turbine;

Figure 3 is a schematic of the combustion turbine system with a portion of the fuel line disposed in the heat recovery steam generator; and

Figure 4 is a schematic of the combustion turbine system with a portion of the fuel line disposed in a separate section of the heat recovery steam generator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, the combustion turbine system 20 comprises an electric generator 22 connected by rotor 24 to compressor 26 and combustion turbine 28 all in a manner well known in the art. A combustor 30 which may be chosen from those well known in the art is connected at one end to compressor 26 and at the other end to turbine 28.

An air intake line 32 is connected to compressor 26 for providing air to compressor 26. First pipe 34 connects compressor 26 to combustor 30 for directing the air compressed by compressor 26 into combustor 30. Combustor 30 combusts compressed air and fuel in a know manner to produce a hot compressed motive gas. The motive gas is conducted from combustor 30 by second pipe 36 to turbine 28 for driving turbine 28. Turbine 28 driven by the motive gas turns rotor 24 which drives compressor 26 and generator 22 thereby producing electricity in a manner well known in the art.

The discharge from turbine 28 is conducted by third pipe 38 to exhaust stack 40 from where the exhaust gas from turbine 28 is discharged to the atmosphere. Typically, the temperature of the exhaust gas in stack 40 exceeds 800°F. It is this waste heat which is desirable to utilize.

A fuel line 50 extends from a source of fuel, not shown, to combustor 30 for delivering fuel to combustor 30. Fuel line 50 may have a heat exchange portion 52 disposed in stack 40 in heat transfer relationship with the hot exhaust gas traveling through stack 40. Fuel line 50 may convey a liquid fuel or a gaseous fuel such as methane as is customary in combustion turbine systems. In practice, heating of liquid fuels may be limited to a low temperature, about 200°F, to prevent thermal decomposition of the fuel's constituents. Natural gas, however, may generally be heated up to 1000°F, depending on the fraction of higher hydrocarbons present in the gas in addition to methane, which is the primary component. The desired temperature for heating each fuel will depend on the fuel analysis. The temperature should be established to prevent excessive decomposition of the fuel's constituents that could lead to

coking in the combustor or otherwise affect the combustion process.

To control the fuel delivery temperature, combustion turbine system 20 may also comprise a by-pass fuel control system 60.

- 5 Control system 60 may comprise a by-pass fuel line 62 connected to fuel line 50 at a point upstream of heat exchange portion 52 and at another point downstream of heat exchange portion 52 thereby by-passing heat exchange portion 52 as shown in Figure 1. Control system 60 may also comprise a by-pass flow control valve
- 10 64 disposed in by-pass fuel line 62 and a temperature controller 66 electrically connected to fuel line 50 near combustor 30 and electrically connected to control valve 64 for monitoring the temperature of the fuel entering combustor 30 and for varying the amount of unheated fuel passing through by-pass fuel line 62.
- 15 This control function may also be accomplished within the combustion turbine control system. Temperature controller 66 may be a Logix 2000 digital positioner from the Valtek Company, and control valve 64 may be a globe valve or ball valve supplied by the Fisher company. Fuel flowing through fuel line 50 from the
- 20 fuel source is diverted through by-pass fuel line 62 thereby remaining unheated while the remainder flows through heat exchange portion 52 where it is heated. The unheated by-pass flow and the heated flow are then joined in fuel line 50 downstream of heat exchange portion 52 and flow into combustor
- 25 30. The mixing of the unheated and heated fuel in this manner thus lowers the temperature of the heated fuel to a desired level. If it is desired to increase the temperature of the fuel entering combustor 30, temperature controller 66 can be adjusted to a set point that causes control valve 64 to decrease the
- 30 amount of unheated fuel passing through by-pass fuel line 62 and into fuel line 50 downstream of heat exchange portion 52 thereby increasing the temperature of the fuel entering combustor 30.

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Likewise, the flow through by-pass fuel line 62 can be increased by adjusting temperature controller 66 to a lower set point. In this manner the temperature of the fuel entering combustor 30 may be automatically controlled.

5 In a typical 150 MW turbine, fuel enters fuel line 50 from a fuel source at approximately ambient temperature with a portion flowing through by-pass fuel line 62 and the remainder through heat exchange portion 52. The temperature of the exhaust gas flowing through stack 40 at full load is about 1,100°F. With
10 natural gas fuel flowing through heat exchange portion 52 at about 80,000 lb/hr, the fuel exits heat exchange portion 52 at about 600°F to 750°F. Temperature controller 66 may be set to 600°F. In this case control valve 64 is automatically adjusted by temperature controller 66 such that a sufficient amount of
15 unheated fuel which may be approximately 0 to 20,000 lb/hr flows through by-pass fuel line 62 and mixes with the heated fuel in fuel line 52 downstream of heat exchange portion 52 thereby reducing the temperature of the fuel in the line to about 600°F.

In another embodiment to the system, a direct fuel line 68
20 having a flow control valve therein may be incorporated which extends from fuel line 50 to combustor 30. Direct fuel line 68 provides a means to supply unheated fuel directly to combustor 30. This arrangement would be desired when combustor 30 utilizes separately controlled combustion stages and one of the stages
25 requires unheated fuel for proper operation. An example of this would be a dry low NOx combustor with a diffusing-flame pilot stage and one or more lean combustion stages. The design of the pilot stage may require that it be supplied with unheated fuel whereas the lean combustion stages may be optimized for burning
30 heated fuel.

Combustion turbine system 20, therefore, provides a means by which the temperature of the fuel delivered to combustor

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30 may be accurately and automatically controlled. Control of
fuel temperature is particularly important in dry low NOx
combustion turbines because the lean combustion stages of such a
combustor may be optimized for fuel at a particular temperature
5 and may not achieve the desired levels of emissions if the fuel
is at a significantly different temperature.

Referring now to Figure 2, as an alternative, stack 40
may have a by-pass channel 70 connected to it such that a portion
of the exhaust gas flows through channel 70. Channel 70 may have
10 a damper 72 disposed therein for controlling the amount of
exhaust gas flowing through channel 70. In this alternative,
heat exchange portion 52 of fuel line 50 may be disposed in
channel 70 downstream of damper 72 such that the flow of exhaust
gas in heat exchange relationship with heat exchange portion 52
15 may be controlled or eliminated by adjusting damper 72 either
manually or automatically.

Figure 3 shows a variation of combustion turbine sys-
tem 20 wherein heat exchange portion 52 is disposed in heat
recovery steam generator 80. In this embodiment, the exhaust gas
20 from turbine 28 flows through heat recovery steam generator 80
and in heat transfer relationship with heat exchange portion 52
disposed therein.

Figure 4 discloses a variation of the embodiment shown
in Figure 3 wherein heat recovery steam generator 80 has a by-
pass passage 82 through which a portion of the exhaust gas flows.
Valve 84 is located between the main section of heat recovery
steam generator and passage 82 to control the flow of exhaust gas
through passage 82 and in heat transfer relationship with heat
exchange portion 52 disposed in passage 82.
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30 The invention may be embodied in other specific forms
without departing from the spirit of the present invention.

Therefore, the invention provides a combustion turbine
fuel heating system that is simple, economical, will allow the
fuel to be heated above 600°F, if desired, and can be used in a
35 simple or combined cycle combustion turbine power plant.

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We claim as our invention:

1. A combustion turbine system comprising:
a compressor for compressing air for combustion;
a combustor connected to said compressor for
5 receiving compressed air from said compressor and for receiving
fuel with said compressed air and said fuel being combusted
therein and producing a combustion gas;
a turbine connected to said combustor and
arranged to receive said combustion gas for driving said turbine
10 with said combustion gas being exhausted from said turbine; and
a fuel line connected to a source of said fuel
and connected to said combustor with a portion of said fuel line
being disposed in heat transfer relationship with said combustion
gas thereby heating said fuel prior to being introduced into said
15 combustor.
2. The combusting turbine system according to claim
1 wherein said portion of said fuel line is disposed in heat
transfer relationship with said combustion gas which has been
exhausted from said turbine.
- 20 3. The combustion turbine system according to claim
2 wherein said portion of said fuel line is disposed in heat
transfer relationship with said combustion gas downstream of said
turbine.
- 25 4. The combustion turbine system according to claim
3 wherein said system further comprises an exhaust stack
connected to said turbine for exhausting said combustion gas to
the atmosphere.
- 30 5. The combustion turbine system according to claim
4 wherein said portion of said fuel line is disposed in said
exhaust stack and in heat transfer relationship with said
combustion gas.
6. The combustion turbine system according to claim
5 wherein said system further includes a by-pass fuel system for
directing unheated fuel to said combustor.

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7. The combustion turbine system according to claim 6 wherein said by-pass fuel system comprises a by-pass fuel line connected to a source of said fuel and connected to said combustor for delivering unheated fuel to said combustor.

5 8. The combustion turbine system according to claim 7 wherein said by-pass fuel system further comprises control means connected to said fuel line for controlling the amount of said heated fuel and the amount of said unheated fuel being delivered to said combustor.

10 9. The combustion turbine system according to claim 8 wherein said control means comprises:

control valve means disposed in said by-pass fuel line for varying the amount of fuel passing therethrough; and

15 temperature controller means electrically connected to said fuel line downstream of said by-pass fuel line and electrically connected to said control valve means for sensing the temperature of said fuel entering said combustor and for adjusting the flow of said unheated fuel in said by-pass fuel line.

20 10. The combustion turbine system according to claim 9 wherein said portion of said fuel line is disposed in a by-pass channel of said exhaust stack.

25 11. The combustion turbine system according to claim 10 wherein said by-pass channel has a damper disposed therein for controlling the flow of said combustion gas therethrough.

12. The combustion turbine system according to claim 11 wherein said control valve means comprises a globe valve.

30 13. The combustion turbine system according to claim 12 wherein said temperature controller means comprises a digital positioner.

35 14. The combustion turbine system according to claim 3 wherein said combustion turbine system further includes a by-pass fuel system for directing unheated fuel to said combustor.

15. The combustion turbine system according to claim 14 wherein said by-pass fuel system comprises a by-pass fuel line connected to a source of said fuel and connected to said combustor for delivering unheated fuel to said combustor.

40 16. The combustion turbine system according to claim 15 wherein said by-pass fuel system further comprises control means connected to said fuel line for controlling the amount of

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said heated fuel and the amount of said unheated fuel being delivered to said combustor.

17. The combustion turbine system according to claim 16 wherein said control means comprises:

5 control valve means disposed in said by-pass fuel line for varying the amount of fuel passing there-through; and

temperature controller means electrically connected to said fuel line downstream of said by-pass fuel line and electrically connected to said control valve means for sensing
10 the temperature of said fuel entering said combustor and for adjusting the flow of said unheated fuel in said by-pass fuel line.

18. The combustion turbine system according to claim 17 wherein said combustion turbine system further comprises a
15 heat recovery steam generator located downstream of said turbine with said combustion gas flowing there-through, and with said portion of said fuel line being disposed in said heat recovery steam generator and in heat transfer relationship with said combustion gas.

19. The combustion turbine system according to claim 18 wherein said heat recovery steam generator comprises a by-pass passage wherein said portion of said fuel line is disposed in the path of said combustion gas.

20. The combustion turbine system according to claim 25 19 wherein said heat recovery steam generator further comprises a valve disposed in said by-pass passage for controlling the flow of combustion gas there-through.

21. A method of operating a combustion turbine system comprising:

30 combusting air and fuel thereby generating a combustion gas;

directing said combustion gas through a turbine for driving said turbine;

35 exhausting said combustion gas from said turbine, and directing said combustion gas in heat transfer relationship with a portion of a fuel line thereby heating said fuel therein; and conducting said heated fuel into said combustor.

22. The method according to claim 21 wherein said method further comprises mixing unheated fuel with said heated
40 fuel prior to introduction into said combustor.

23. The combustion turbine system according to claim 3 wherein said combustion turbine system further comprises a heat

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recovery steam generator located downstream of said turbine with said combustion gas flowing therethrough, and with said portion of said fuel line being disposed in said heat recovery steam generator and in heat transfer relationship with said combustion gas.

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ABSTRACT OF THE DISCLOSURE

5 The combustion turbine system comprises a fuel line
connected to the combustor with a portion of the fuel line being
disposed in heat transfer relationship with the exhaust gas from
the combustion turbine so that the fuel may be heated by the
exhaust gas prior to being introduced into the combustor. The
system may also comprise a fuel by-pass control system for mixing
unheated fuel with the heated fuel to control the temperature of
10 the fuel being introduced into the combustor.

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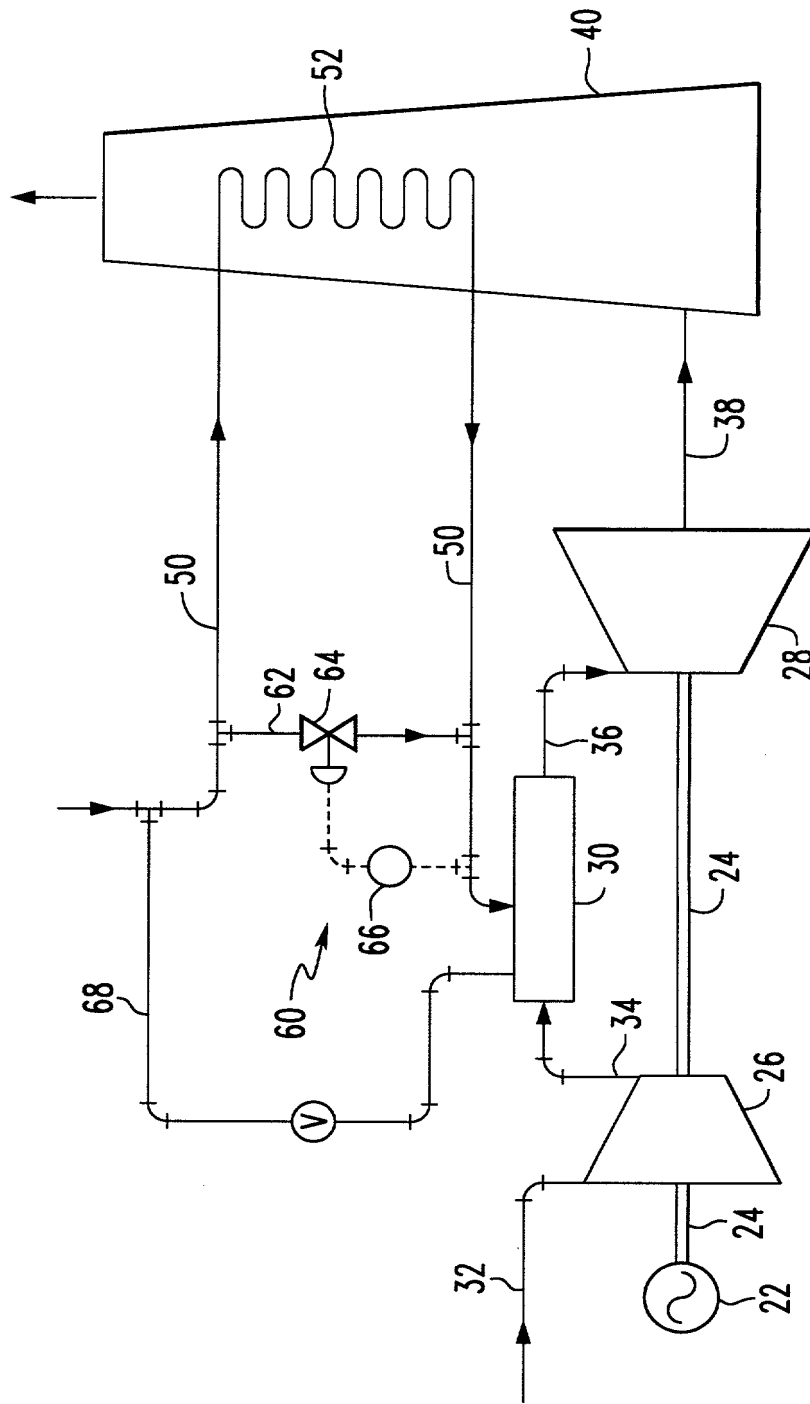


FIG. 1

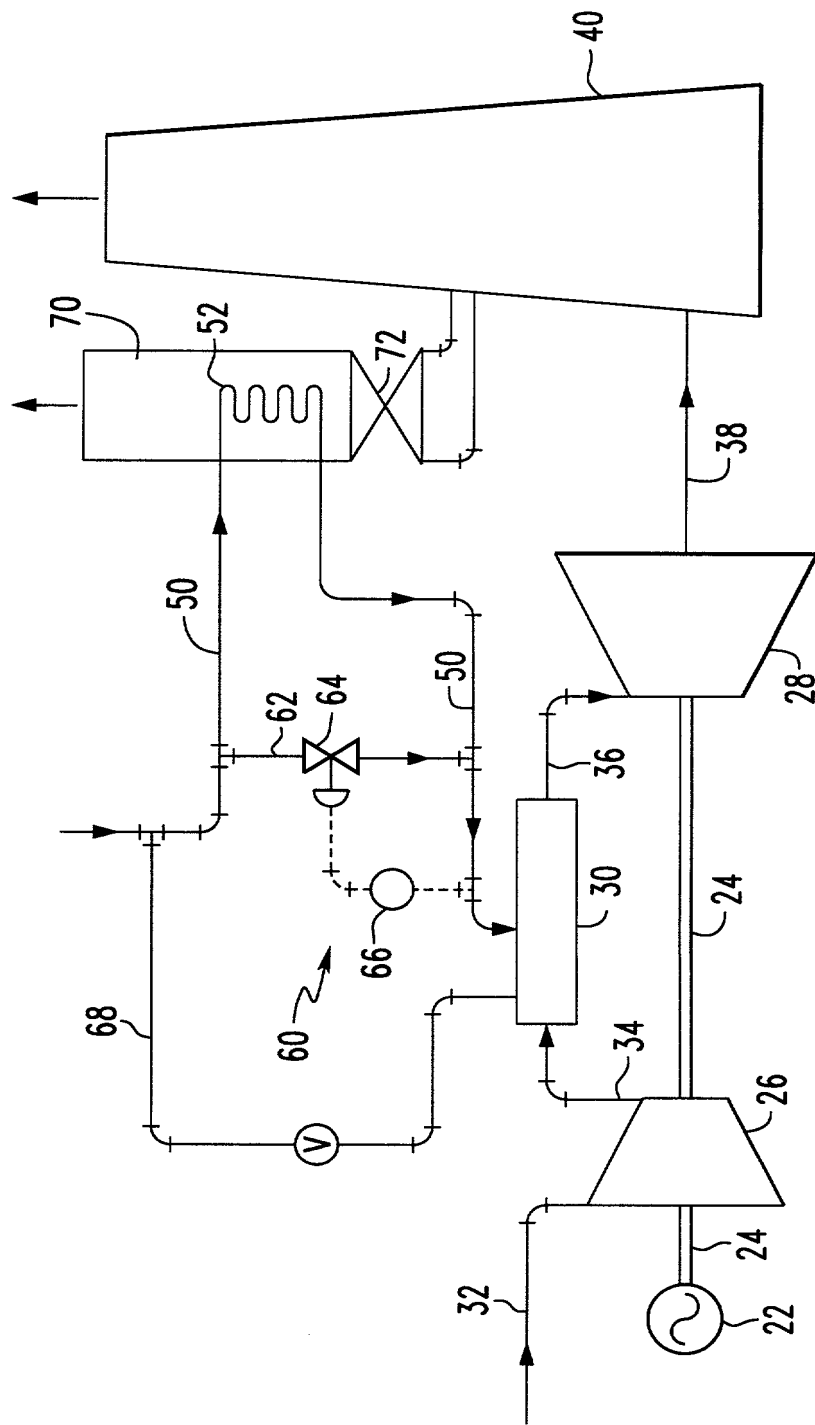


FIG. 2

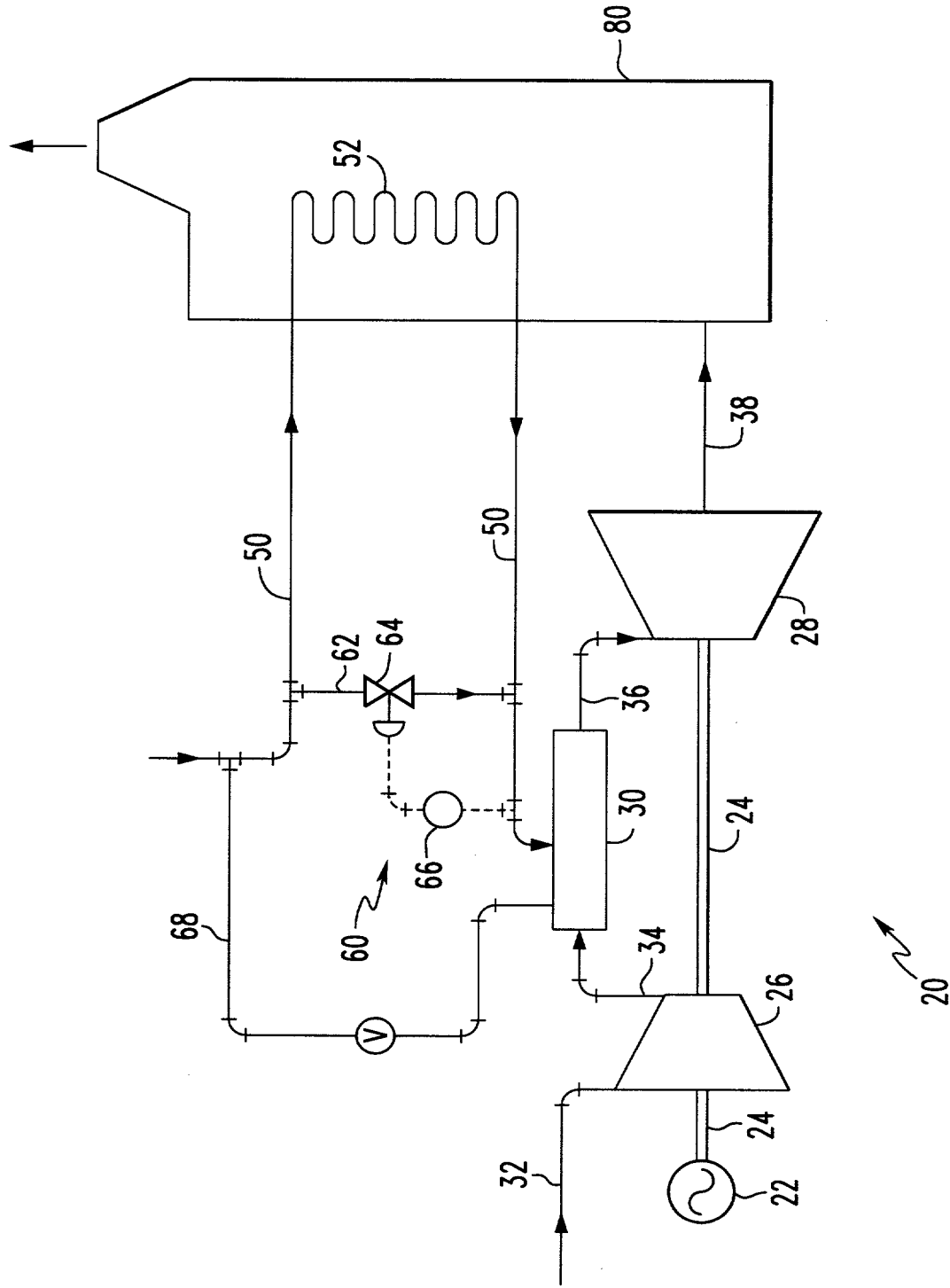


FIG. 3

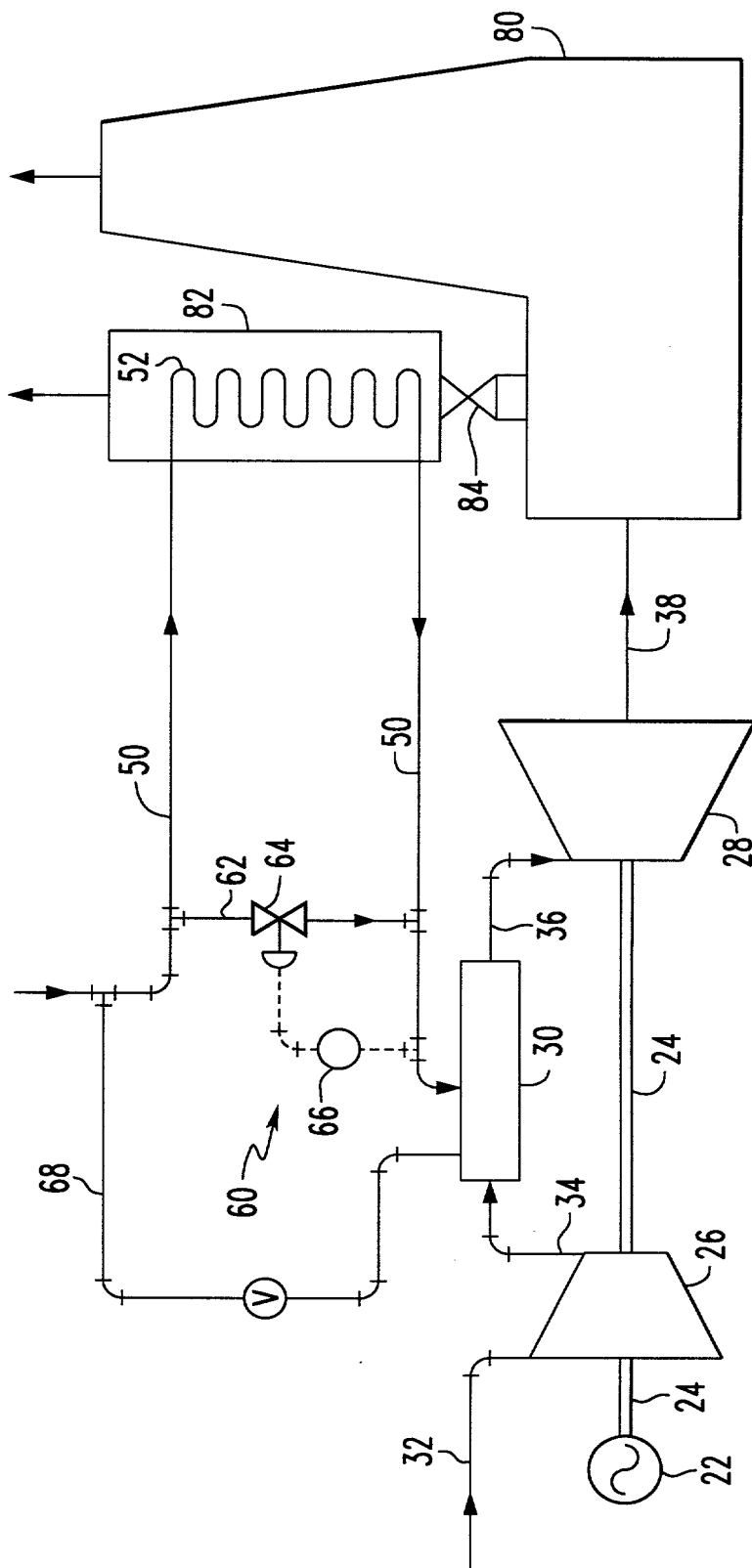


FIG. 4

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DECLARATION AND POWER OF ATTORNEY
Original Application

As a below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

COMBUSTION TURBINE WITH FUEL HEATING SYSTEM

the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, 1.56(a).

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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